KAREN HAYDOCK

HOW DO THEY EVOLVE?

ISBN 978-81-237-7371-1

First Edition 2015 (*Saka* 1936)

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₹ 130.00

Published by the Director, National Book Trust, India
Nehru Bhawan, 5 Institutional Area, Phase-II
Vasant Kunj, New Delhi - 110070
Website: www.nbtindia.gov.in

Many many years ago,
before your parents were born,
and before your parents' parents were born,
and before their parents', parents', parents were born,
there were different food plants than there are now.

Before this, there was even a time when there were no fields of crops grown by farmers - in fact, there were no farmers! People gathered food that was growing wild instead of growing it in fields.

In the days when farming was just beginning, there were some kinds of wild mustard plants.

Our ancestors took seeds from this wild mustard and planted them in fields.

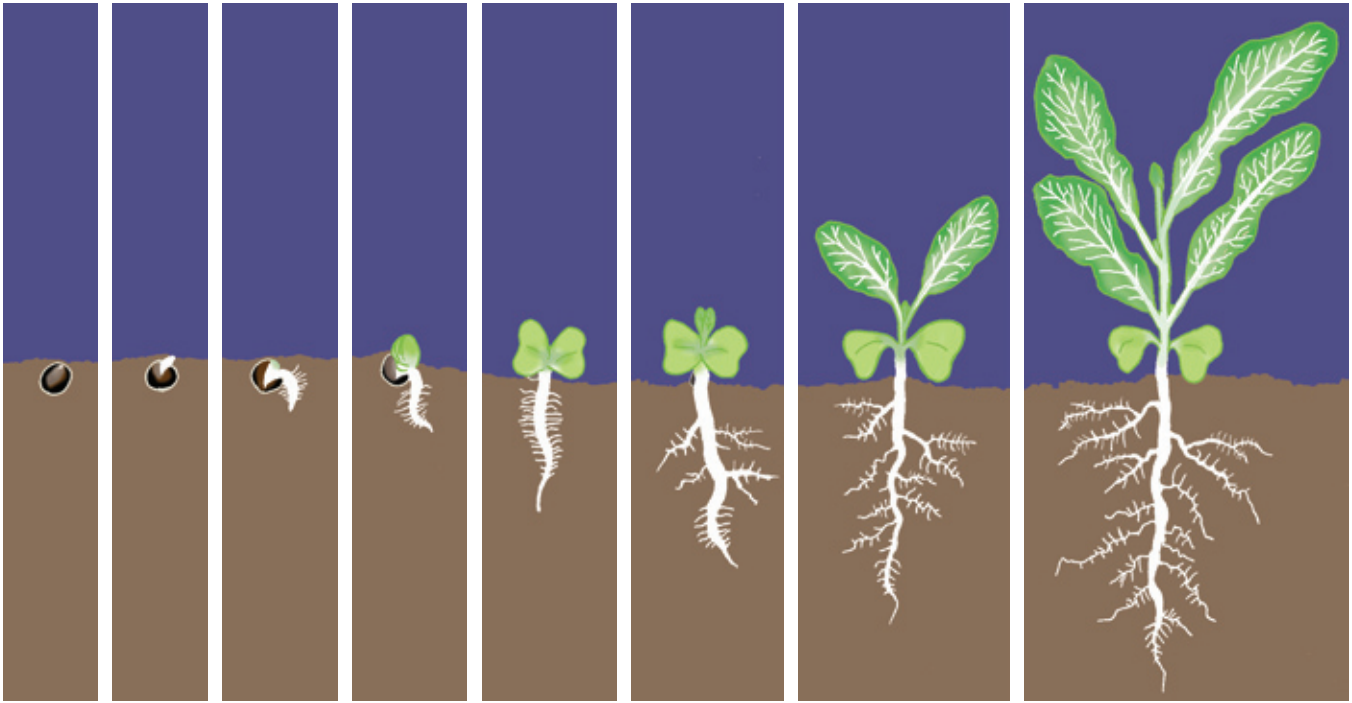
They took
good care...

The mustard seeds sprouted.

The roots grew into the soil.

The shoots grew into the air.

Some buds grew into leaves.



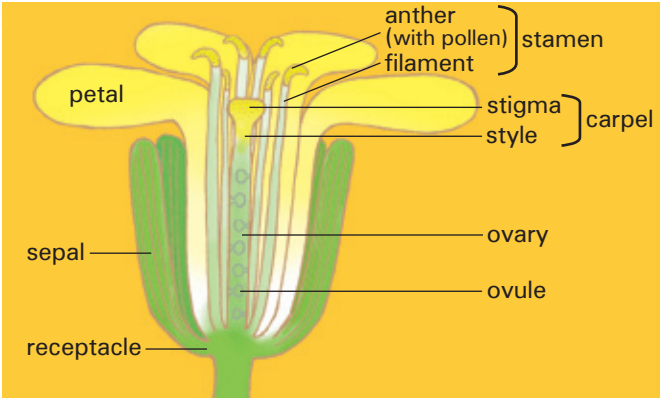
Green leaves grew larger.

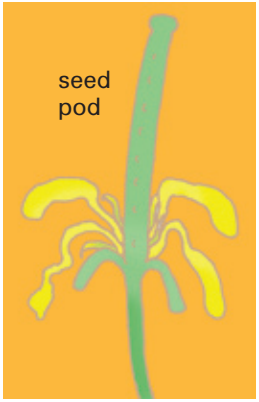
The plants grew taller.

Some buds grew into flowers.

Flowers got pollinated.

Pollinated flowers grew into seed pods.





People noticed some differences between the mustard plants.
Look closely.
Can you see any two plants that are the same?

In what ways are they similar?
In what ways are they different?

Why are they different?
Is it because some had more water?
Or less sun?
Or more fertile soil?
Or is it because the seeds they grew
from were different?

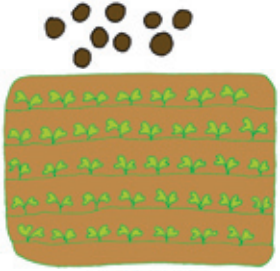
Once some people observed that some mustard plants have seedpods that are longer and contain more mustard seeds than others. They wondered why. They used science to find out.

They QUESTIONED: Why are some mustard seed pods longer than others?

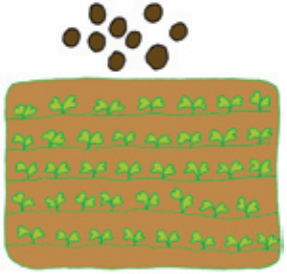
They HYPOTHESIZED: Maybe it is because of the seeds from which the plants grew. Maybe seeds from plants with longer pods produce new plants with longer pods.

They did an EXPERIMENT:

They planted seeds from short pods in Plot A



They planted seeds from long pods in Plot B



They got RESULTS and ANALYSED the results:

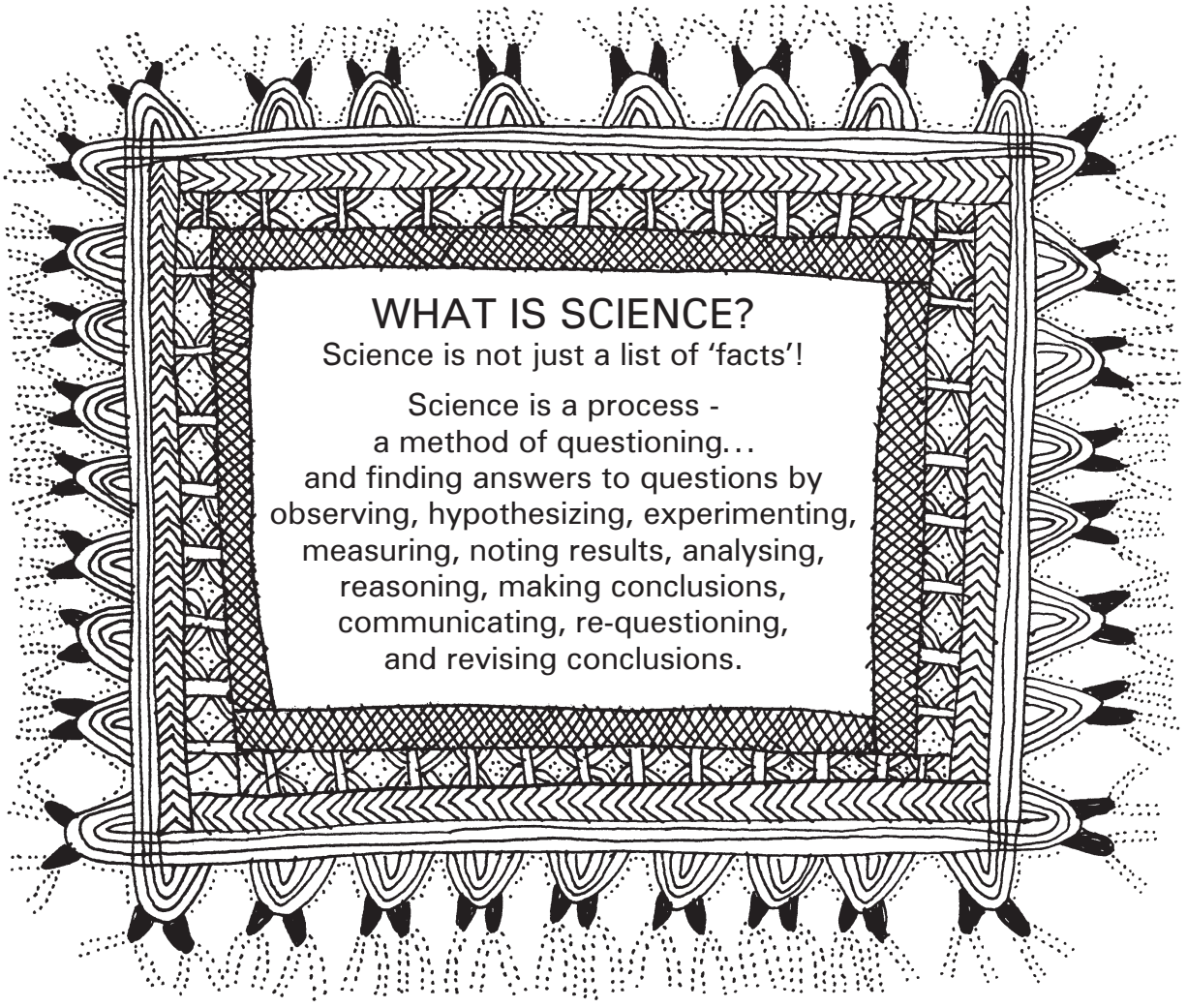
Harvest from Plot A

Harvest from Plot B

They CONCLUDED:

The seeds determine the size of the seedpods ...more or less.

They asked MORE QUESTIONS: Why are a few of the seed pods from Plot B short? Did both plots produce the same number of seed pods? Is the taste of the mustard seeds the same?


WHAT IS SCIENCE?
Science is not just a list of 'facts'!
Science is a process -
a method of questioning...
and finding answers to questions by
observing, hypothesizing, experimenting,
measuring, noting results, analysing,
reasoning, making conclusions,
communicating, re-questioning,
and revising conclusions.

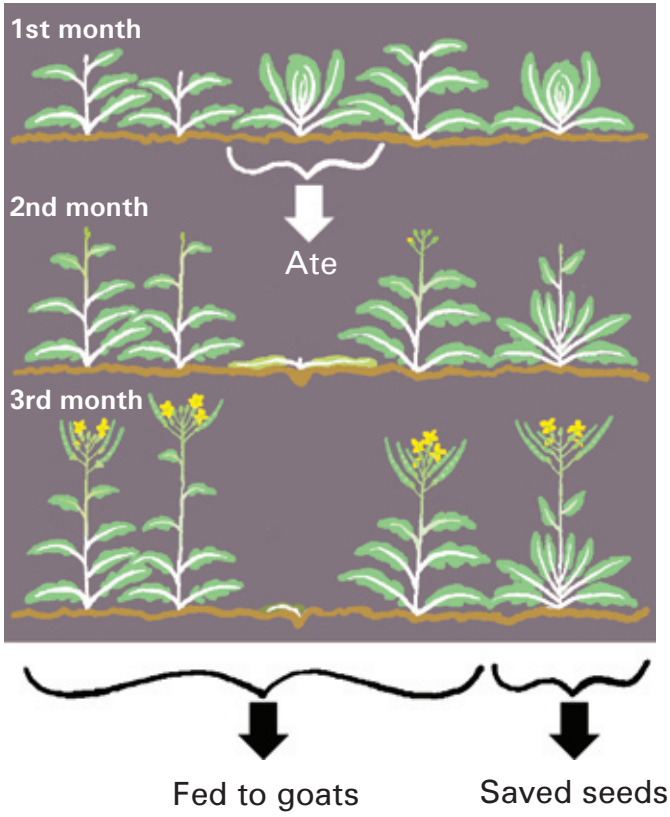
There is a lot of variation in the scientific method. The order is not fixed, and not all of these processes are always included.

Some of our ancestors liked to eat the young mustard leaves that were packed closely together.

They were very tasty!

The farmers needed to collect seeds to grow the next year's crop. Instead of eating all the plants, they let some plants grow and produce flowers and seeds.

They wanted to get more plants with tightly packed leaves, so they selected seeds from the plants that had started out with tightly packed leaves.



They planted these seeds the next year.

Each year they selected seeds from the plants with tightly packed leaves.

If all the best plants were eaten, then the worst plants would be the only ones left to produce seeds for the next year's crop.

After many years, what did they get?
bandgobi!

Had one plant changed from having less tightly packed leaves to having more tightly packed leaves?

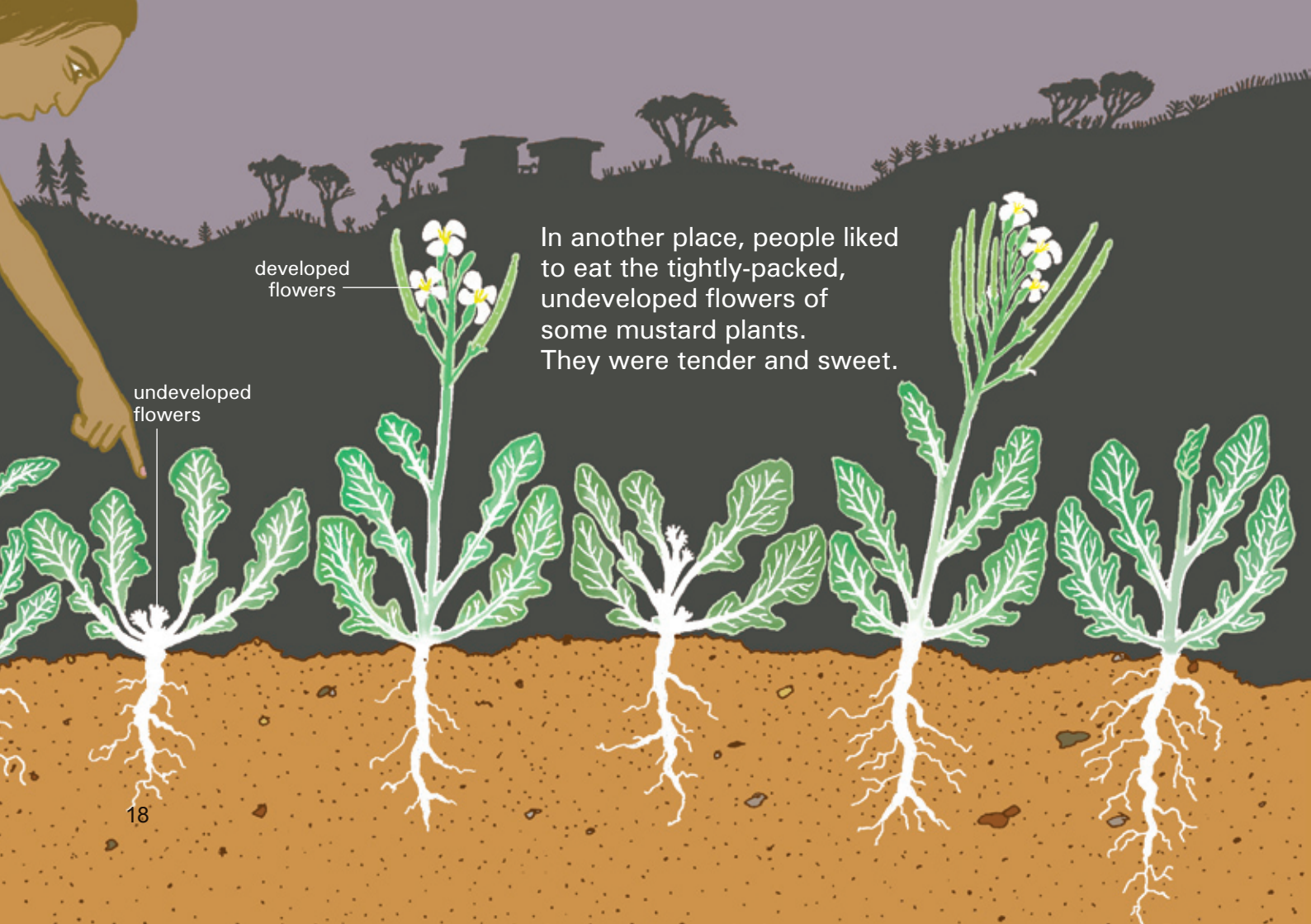
No!

An individual wild mustard plant did not change into a cabbage plant.

Plants that happened to have tightly packed leaves were the ones that farmers selected for seeds.

The **population** of plants changed after many generations of selection.

A population in which only a few plants had tightly packed leaves evolved into a population in which most plants had tightly packed leaves.


developed flowers
undeveloped flowers
In another place, people liked to eat the tightly-packed, undeveloped flowers of some mustard plants. They were tender and sweet.

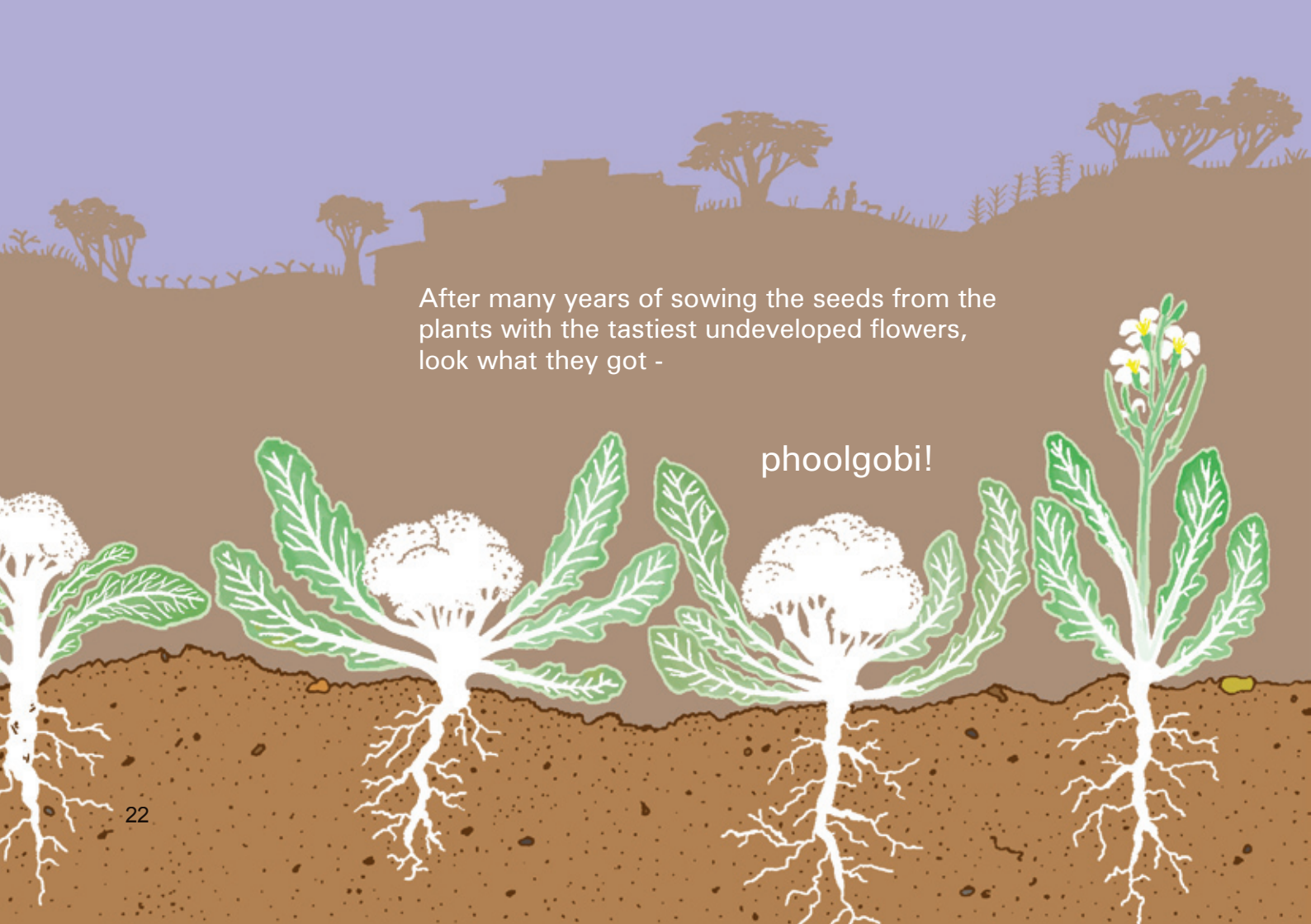
A few of the undeveloped flowers went on to produce flowers and seeds.

The farmers gathered the seeds from these plants, and planted them the next year.

The seeds sprouted and the new crop grew.

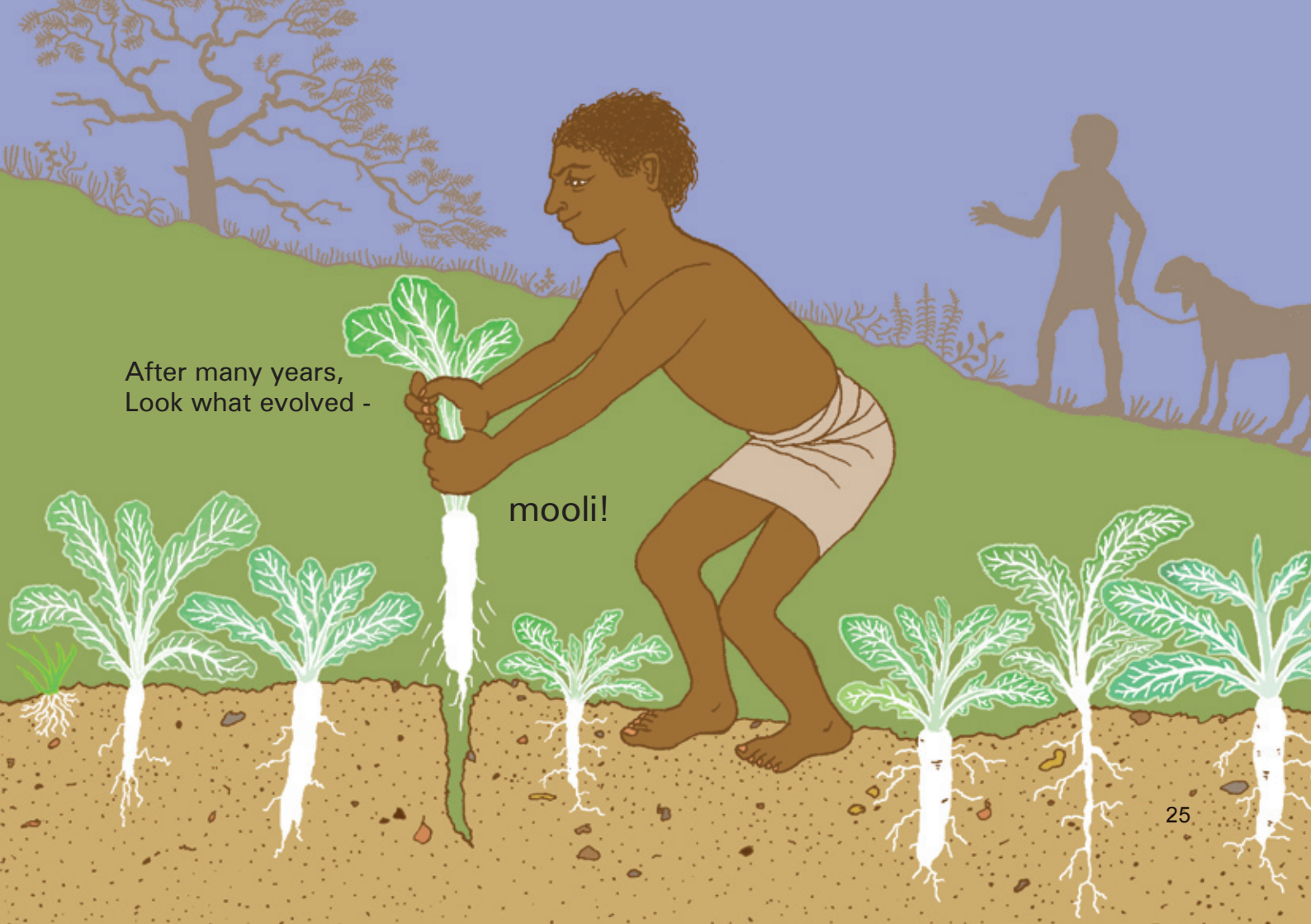
Look - this crop has more plants with larger and better tasting undeveloped flowers.

At the end of the season,
the farmers again chose
the seeds from the
plants with the best
undeveloped flowers.

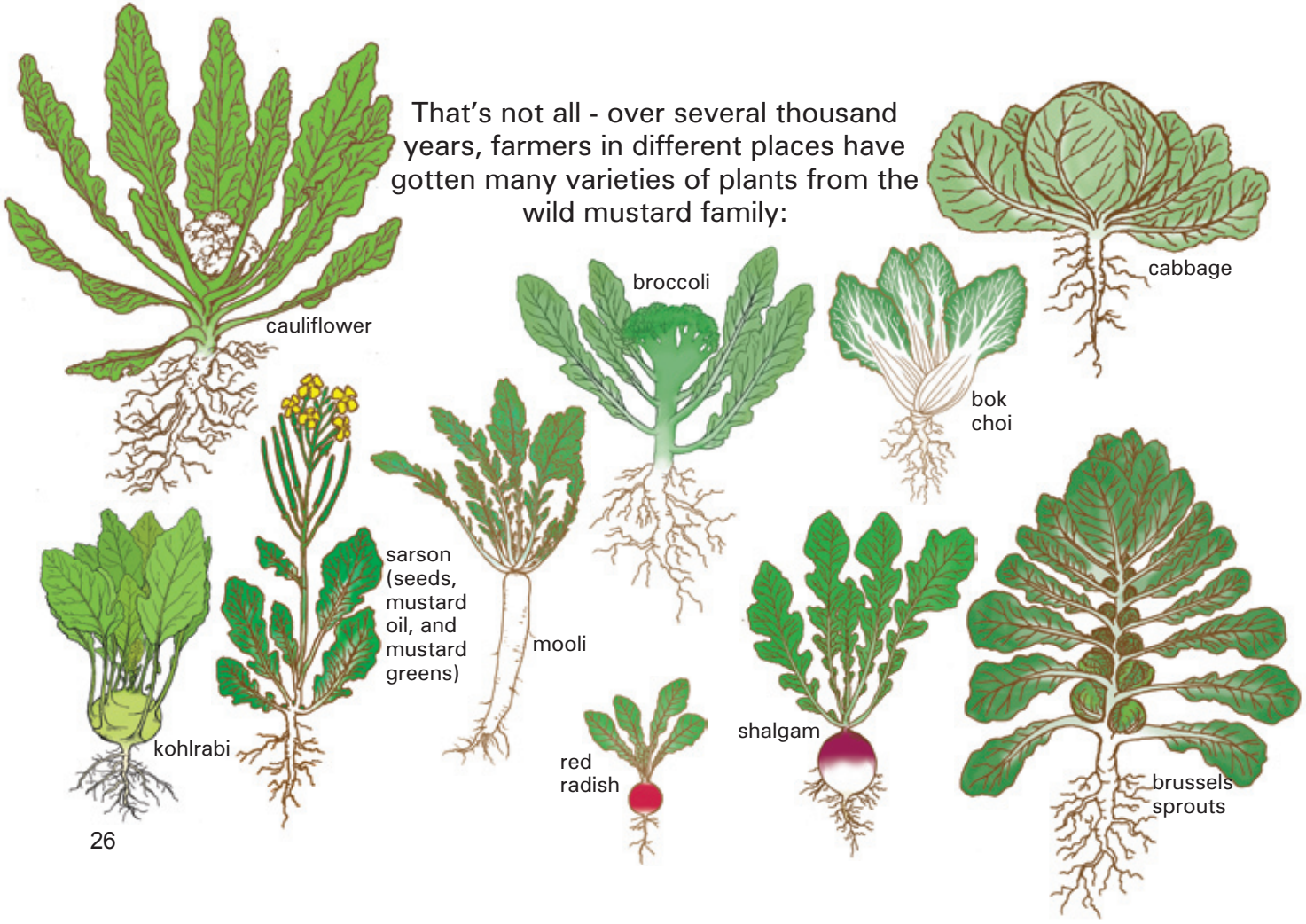

After many years of sowing the seeds from the plants with the tastiest undeveloped flowers, look what they got -
phoolgobi!

In yet another place, people found another kind of wild mustard.
Some of its roots were thick and juicy. They tasted good.
So they planted the seeds from these plants.

Each year farmers saved the seeds that gave plants with thick, tasty roots, and they used them to plant the next crop.


After many years,
Look what evolved -
mooli!

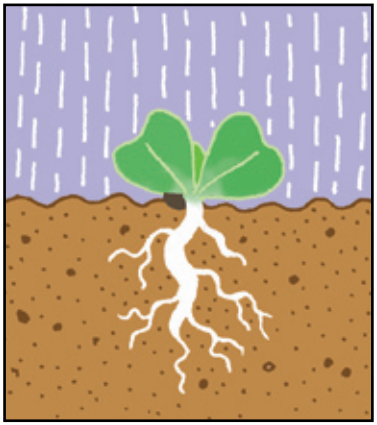
That's not all - over several thousand years, farmers in different places have gotten many varieties of plants from the wild mustard family:



All of these were produced by people selecting the kinds of plants they wanted.

This is called **artificial selection**.

Here ‘artificial’ means ‘produced by people’.



Sometimes people don't get what they want by artificial selection.

Sometimes a plant has larger roots just because the plant got more water.

Seeds from these plants may grow into plants with small roots the next year, if they do not get so much water.

The size of the roots is not determined just by the seeds.

Sometimes seeds from plants with one desirable characteristic end up producing new plants with some unwanted characteristic.

For example, we may get a larger cabbage, but it may be bitter.

One characteristic may affect another characteristic.

Artificial selection is one of the methods farmers and scientists continue to use to produce new kinds of plants and animals. By selecting certain individuals for breeding, we may be able to get bigger potatoes, sweeter grapes, faster growing wheat, cows that give more milk, and chickens that are healthier.

Once, some people said,
"We want mustard leaves that taste like mango!"

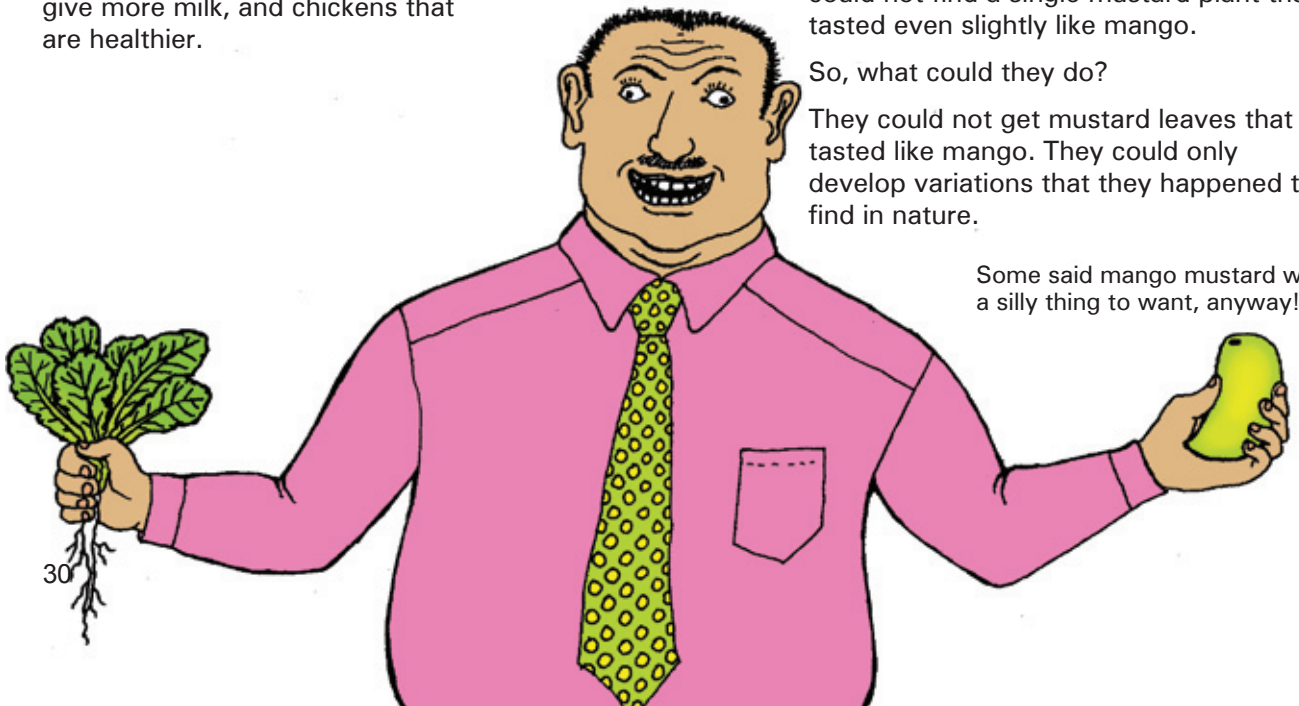
Do you think it is possible?

They looked everywhere for a mustard plant that tasted like mango. But they could not find a single mustard plant that tasted even slightly like mango.

So, what could they do?

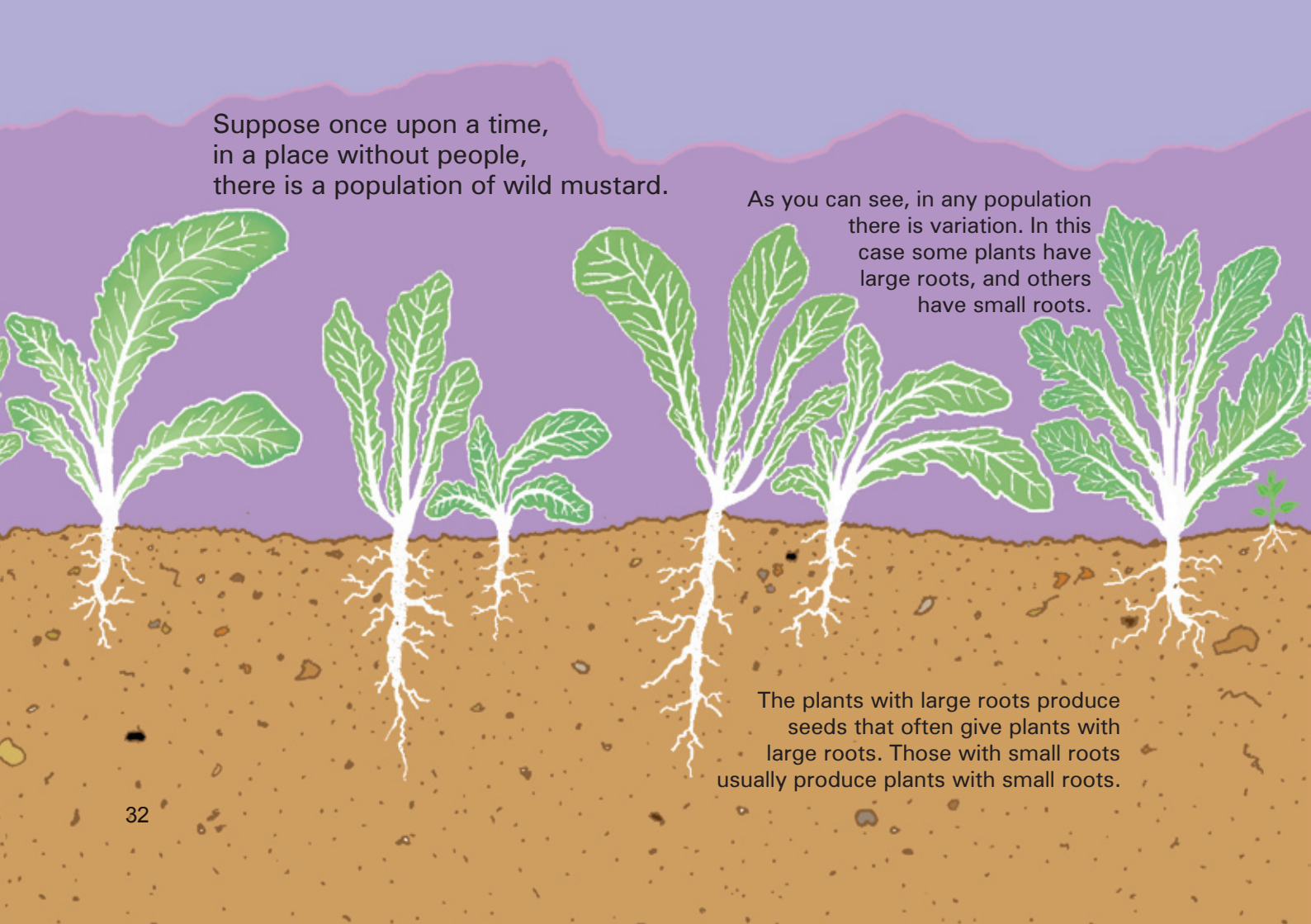
They could not get mustard leaves that tasted like mango. They could only develop variations that they happened to find in nature.

Some said mango mustard was a silly thing to want, anyway!

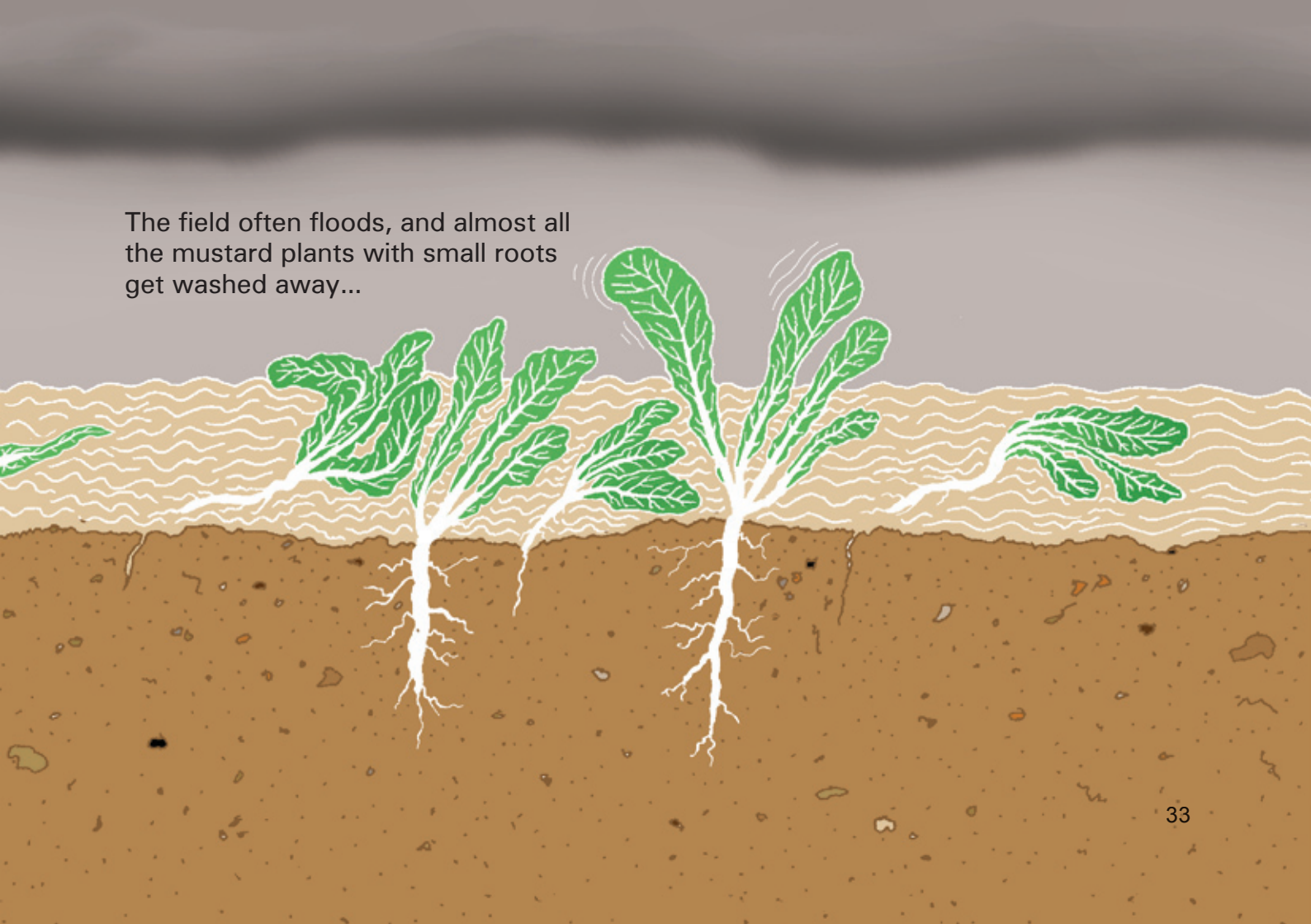


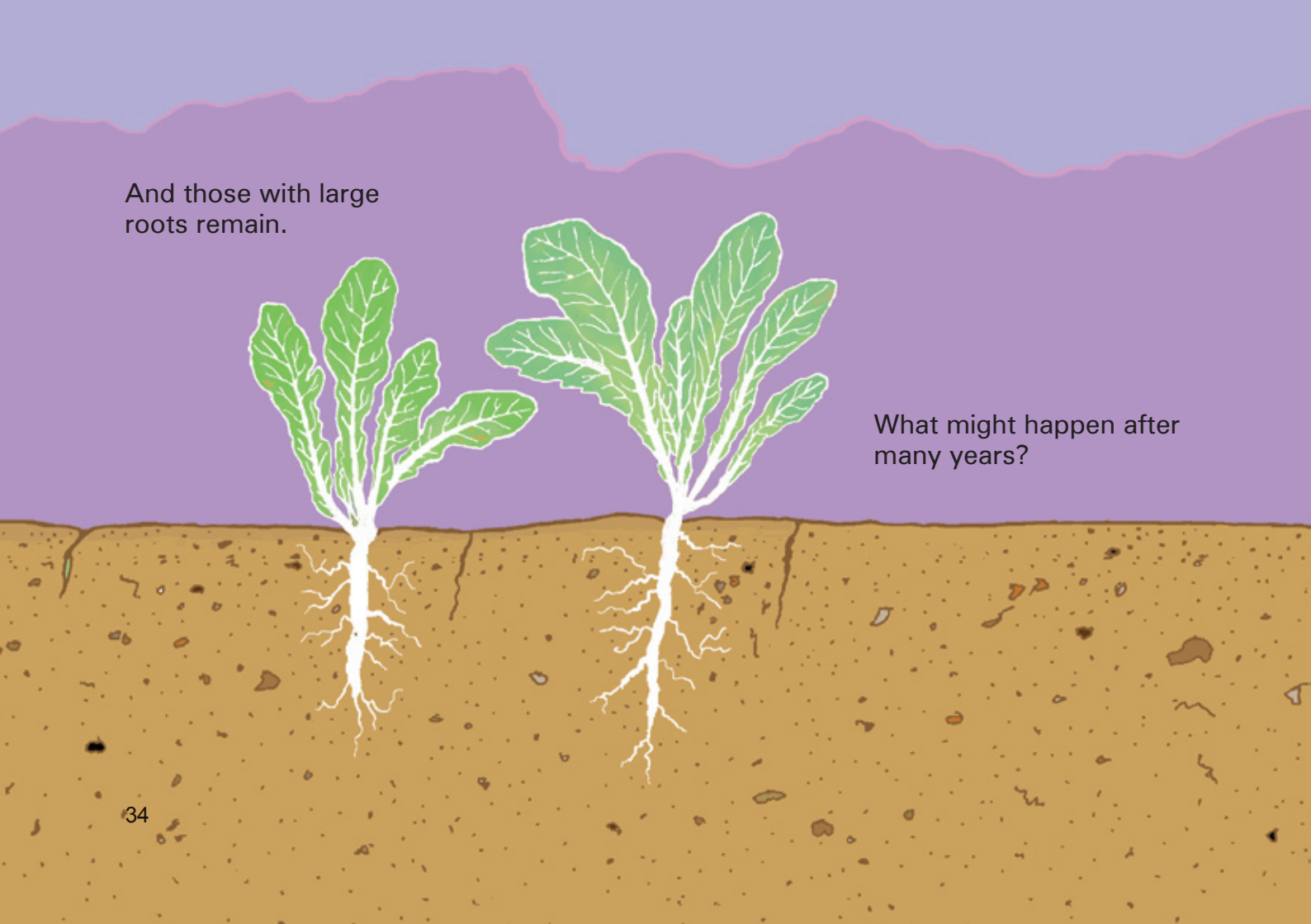
Now, suppose there were no people.

Could a similar thing happen without people?
Could wild mustard give rise to mooli without people?
Could it happen without intention?

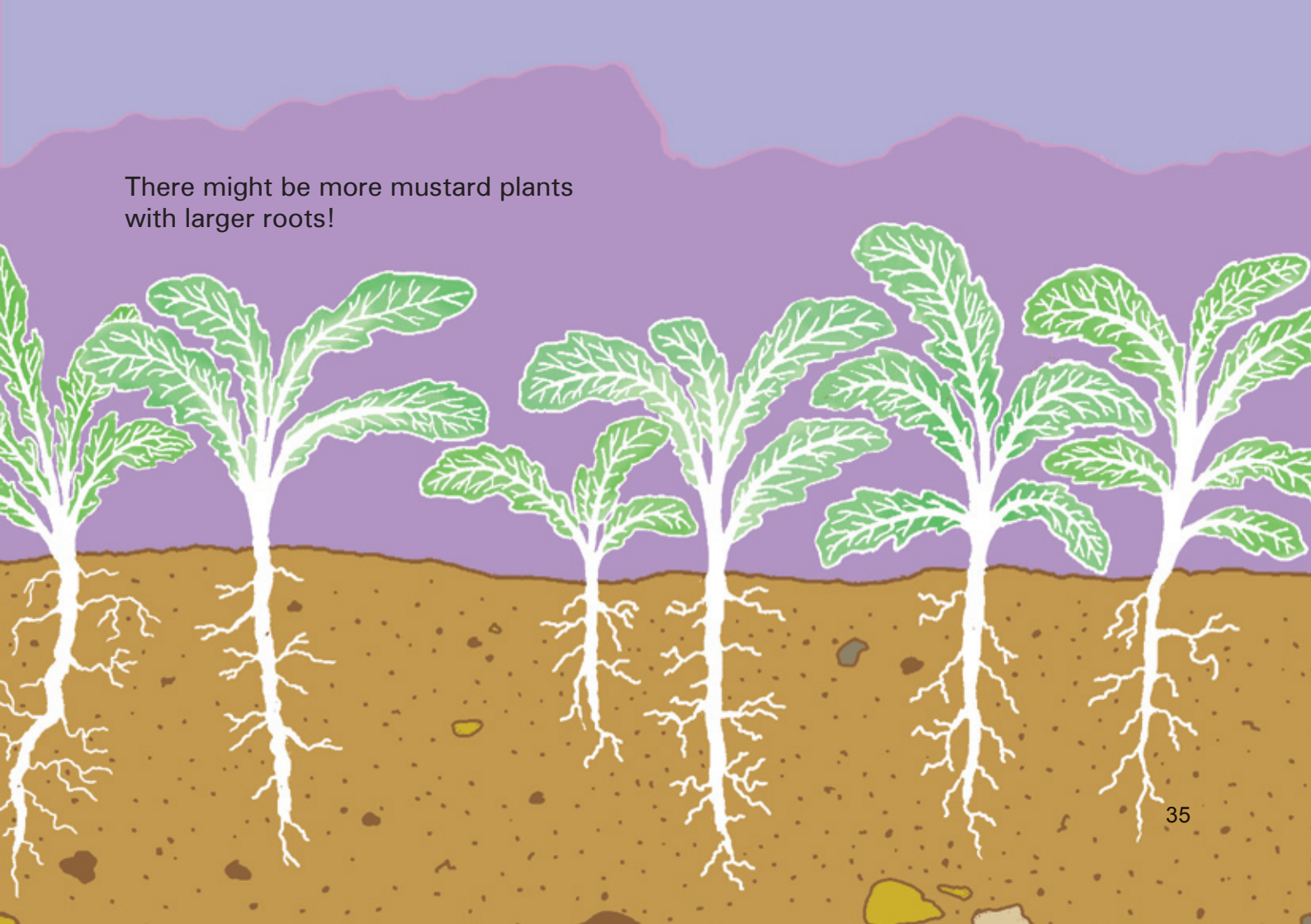

Suppose once upon a time,
in a place without people,
there is a population of wild mustard.
As you can see, in any population there is variation. In this case some plants have large roots, and others have small roots.
The plants with large roots produce seeds that often give plants with large roots. Those with small roots usually produce plants with small roots.

The field often floods, and almost all the mustard plants with small roots get washed away...



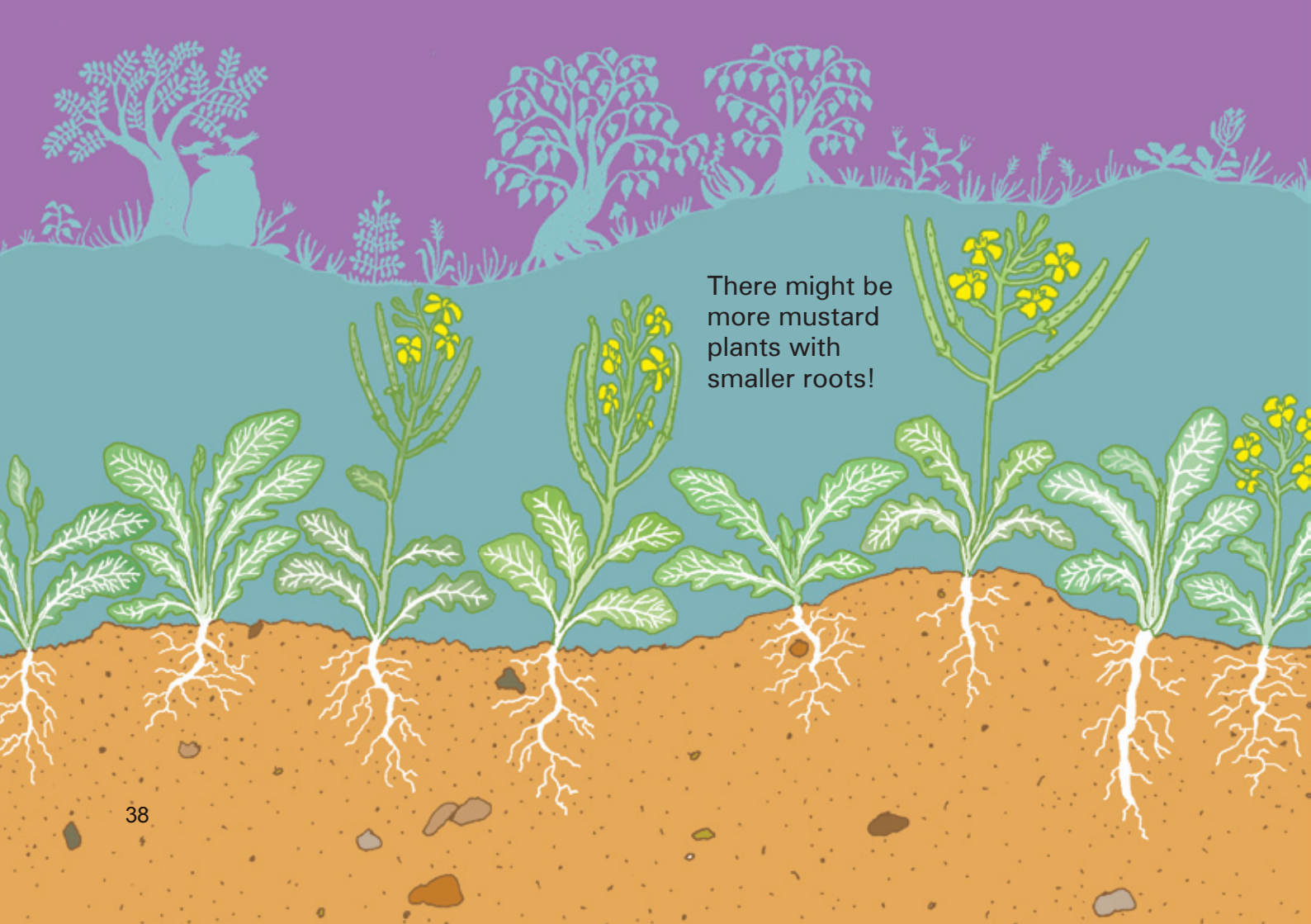

And those with large roots remain.
What might happen after many years?

There might be more mustard plants with larger roots!



Or, suppose there is
another field of wild mustard...

In this field, some insects come to live.
Suppose the insects eat large mustard roots, but not small mustard roots.
Then, what might happen?


There might be more mustard plants with smaller roots!

This is called **natural selection**.

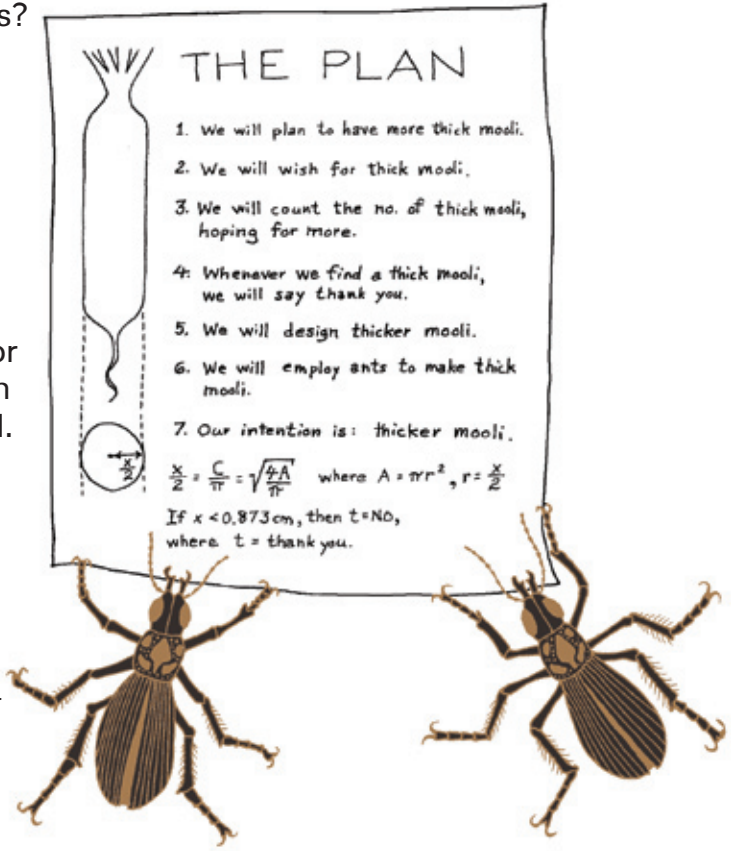
Here ‘natural’ means ‘not produced by people’.

The population of mustard plants evolved.
The change in the population may or may not be a large or sudden change. In this example, the change was not as large as what the farmers got, but the population of mustard did change.

Natural selection is very different from artificial selection.
In artificial selection, farmers choose the kinds of plants they want.
In natural selection, nobody chooses what they want.
There is no plan.
There is no design.

Did the mustard want to get large roots?
Do plants have desires?
What did the insects want?
Do insects have desires?

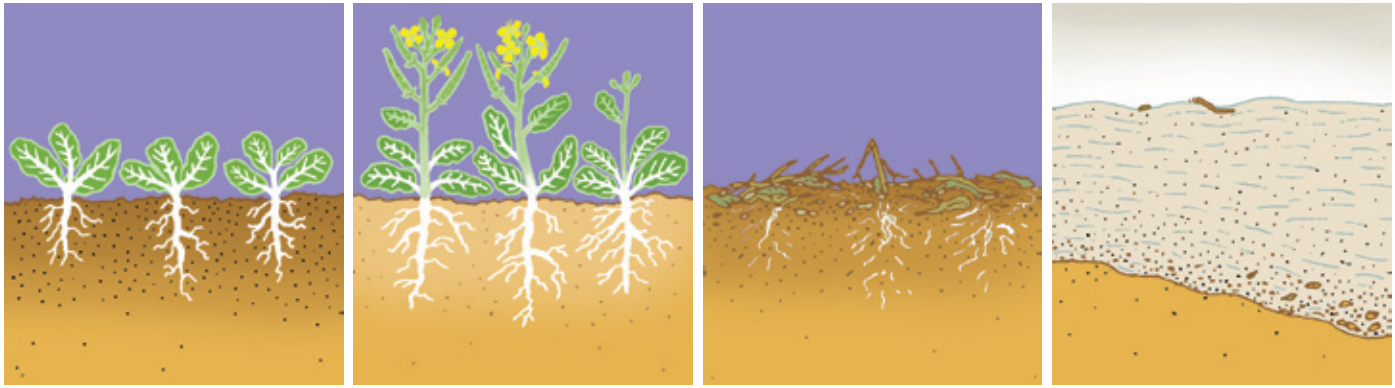
If the insects did have a desire, they would have liked to have more plants with larger, thicker roots - but they got just the opposite. In another case, a plant may evolve that is a good food for a certain animal, but it will not evolve in order to be a good food for that animal.


THE PLAN
1. We will plan to have more thick mooli.
2. We will wish for thick mooli.
3. We will count the no. of thick mooli, hoping for more.
4. Whenever we find a thick mooli, we will say thank you.
5. We will design thicker mooli.
6. We will employ ants to make thick mooli.
7. Our intention is: thicker mooli.
If x < 0.873cm, then t=NO,
where t = thank you.

"Training is everything. The peach was once a bitter almond; cauliflower is nothing but cabbage with a college education."

-Mark Twain, Pudd'nhead Wilson, 1894

Organisms affect their environment and the environment affects organisms.



For example, mustard plants remove nutrients from the soil.

When they die and decompose, the plants also add nutrients and organic matter to the soil.

On the other hand, a flood may remove the nutritious topsoil.

Changes in the soil will affect the growth of future generations, and may also make certain variants more or less likely to survive and reproduce.

Many processes are interdependent and interconnected with the process of natural selection.

When we do science, we find evidence that natural selection really does happen, and it causes evolution.

Evolution is the process by which populations of plants, animals, and other living things change over generations.

Individual plants, animals, and other organisms do not evolve.

Populations of organisms evolve.

If the change is great enough, we say that a new species has evolved.

A population is a group of the same kind of living things living in the same place at the same time.

In every population there is variation. No two individuals in a population are exactly alike. Some of the differences can be passed on to future generations (to some extent, they are heritable).

There are a number of mechanisms by which evolution occurs.
In this book we have discussed only two ways:

artificial selection and natural selection.

People can change a population on purpose through artificial selection.

Natural selection does not happen on purpose.

You can't always get what you want!

APPENDIX: A few more things to think about...

When people produce new types of crops through the process of artificial selection, they are doing science.

They ask questions:

"Why do the mustard seeds grown in this field taste more pungent than the mustard seeds grown in that field? Is it because of the soil?"

"Do more seeds sprout if we plant them deeper underground?"

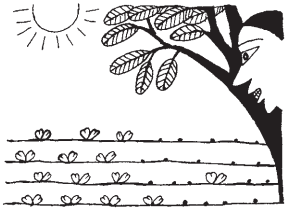
"How can we get larger mooli?"

They make hypotheses and do experiments:

"Let's have the plants closer together in one row and farther apart in the other row, and see which gives a better crop."

"I think the reason the cabbage last year did not form heads was that the weather was too hot. Heat makes the plants grow tall. So this year let's plant the cabbage earlier in the season.

They make observations and analyse results:



"See how shady it is here... I think the reason the seeds did not germinate was that they did not get enough sun on this side."

They communicate:

"The people in the next village have some strange looking cabbage. Maybe we should get some seeds from it."

However, farmers' science has not progressed as much as it could have because farmers did not and do not have access to good education or communication. The Brahminisation of science and the hierarchal structure of education has been a large problem.

Was it really science?

There is a lot of evidence that our ancestors developed new crops like cabbage and cauliflower through artificial selection. The evidence indicates that cabbage and cauliflower were developed several thousand years ago.

But some people do not agree that when our ancestors did this they were doing science. They say that science began more recently in Europe as a result of the Renaissance (which began only in the 14th century). They say that science was what Galileo did when he built a telescope and studied the moons of Jupiter. They say that farmers were not scientists. Farmers were illiterate - they did not write careful records of what they did. They may have made guesses, but they did not make theories or hypotheses. They did not work systemically. They did not have an explicit understanding of artificial selection.

It is true that ancient farmers did not write records of what they did. But maybe we are being biased when we say that science cannot be done without writing. Or maybe we are not recognising the accomplishments of farmers because they were not 'upper caste' or 'upper class' - they were just labourers.

Certainly early farmers must have asked questions like those shown on the opposite page. And they must have learned through a process of trial and error. Aren't experiments also a process of trial and error? In the process of trial and error our ancestors must have also guessed or tried to predict what the results would be. Did they base their predictions on theories which they made through observation, reason and logic? Or did they invent wild stories and myths about spirits and magic, and base their predictions on these myths? Did they believe what authorities said or did they question authorities in order to revise theories and come to new conclusions?

Would it have been possible to develop cabbage and cauliflower if they based their predictions on myths and magic?

What is evolution by natural selection?

(1) There is variation between the individual organisms that make up any population.

(2) This variation occurs partly because there are random mutations in the genome (differences in the DNA) of individual organisms. These mutations can be passed to offspring.

(3) Throughout the individuals' lives, their genomes interact with their environments to cause variations in traits. (The environment of a genome includes the molecular biology in the cell, other cells, other individuals, populations, species, as well as the abiotic environment.)

(4) Individuals with certain variants of the traits may survive and reproduce more than individuals with other variants.

(5) Therefore the population evolves.

How do we know that evolution by natural selection occurs?

(1) We do not find any population without variation.

(2) We know that heritable mutations occur because we find them by DNA sequencing of individuals and their offspring.

(3) We find correlations between mutations and traits. We also observe that mutations cause changes in proteins. However, due to the complex interdependencies between the genome and its environment, we usually cannot say whether a particular mutation causes a particular trait.

(4) We observe that individuals with certain traits survive and reproduce in certain populations. For example, we observe how certain variants of bacteria increase and other variants decrease in a population of bacteria.

(5) We observe evolution - we see that populations do change over generations. If the changes are large enough, we call the population a new species.

Other methods people use to produce new kinds of plants

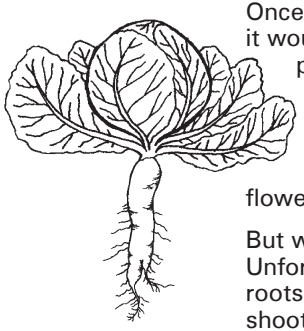
Hybrid plants

By pollinating one kind of plant with the pollen from another variety or related kind of plant, we can breed plants with new characteristics.

Genetic Modification (GM)

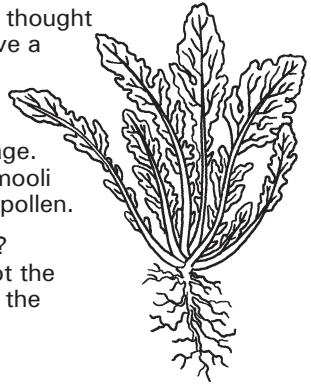
Using modern methods of genetic engineering and molecular biology, new types of plants can be produced.

Scientists have produced many kinds of hybrid rice, hybrid wheat, and hybrid vegetables. Hybrids may have disadvantages as well as advantages. For example, the yield may be greater, but new seeds have to be purchased each year.



Once, some scientists thought it would be nice to have a plant which has the roots of mooli and the shoots of cabbage. They pollinated mooli flowers with cabbage pollen.

But what did they get? Unfortunately, they got the roots of cabbage with the shoots of mooli!

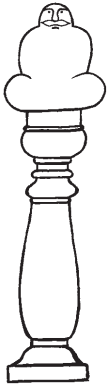


Some questions arise concerning GM crops:

- Will the new plants cause allergies or other diseases in people?
- Will the new plant or its genes give rise to uncontrollable weeds?
- Will the new plant adversely affect insects or other animals? How will it change its environment?
- Will the new plant be more expensive for farmers to grow?

Maybe we could get mangomustard by GM...

but maybe the mangomustard would be poisonous!



Who decides?

No one decides what will happen in **natural selection**.

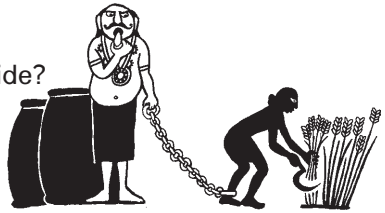
But in **artificial selection** who decides?

Did the people who planted the seeds decide which seeds to plant?

Or did someone else tell them which seeds to plant?

Did the zamindar decide? Did the king decide?

And is it different nowadays? Nowadays does the government decide? Do the seed companies decide? Do ordinary people decide?



If the master decides, what seeds the slave will plant, will the master make the right decision? Some masters may be better than other masters. But there is no such thing as a good master.

How are the decisions made?

Is it based on which plants give the best taste?

The best colour? The largest size?

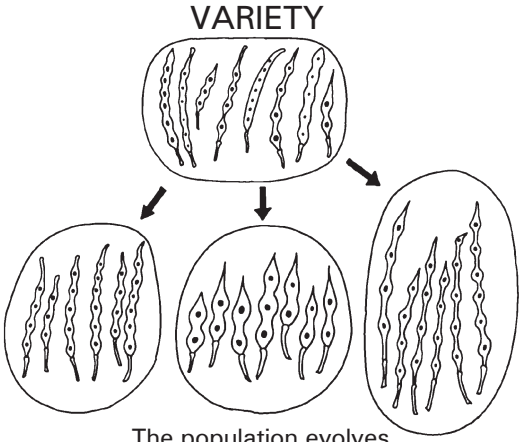
Or is it the ones that are easy to harvest?

Is it decided on the basis of profit and loss?

Is it decided on the basis of need or on the basis of desire?

Are the wrong decisions sometimes made?

Who should make decisions, and on what basis?



The population evolves
(perhaps in three different ways)

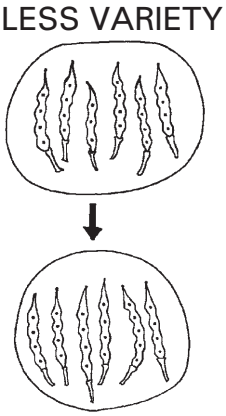
Loss of variety is a serious problem

Nowadays seed companies try to get all farmers to buy a particular kind of seed they have developed. As a result, the number of varieties of many crops are decreasing.

For example, people in the same village, or in different villages, used to grow many different varieties of rice. Now just just a few different kinds are grown.

But everything is interconnected and everything keeps changing. So a variety that was good a few years ago may not be so good now - it may have become less resistant to some new fungus or beetle. We may need to develop new varieties of rice. But how can we do this if we do not have a variety of plants to choose from?

Therefore it is important to encourage a diversity of varieties, and to prevent the extinction of varieties which may one day be useful.



The population
does not evolve

Evolution depends on having populations in which there are a variety of individuals.

Did you believe everything you read in this book? ... I hope not.

If you were thinking like a scientist, you should have been questioning what you read!

For example, how do we know where crops like cabbage and cauliflower came from?

This question is currently being investigated by scientists. Scientists do not find cabbage and cauliflower growing in the wild. But they do find various types of wild mustard plants. This is in line with the possibility that cabbage and cauliflower were produced by artificial selection, not natural selection.

You can find evidence that various plants in the mustard family are related by comparing the forms of their flowers, leaves, roots, and other parts. You can also compare their taste to other vegetables. Scientists have found substances called glucosinolates in plants in the mustard family, which give them a characteristic taste.

By determining the DNA sequences of the wild and cultivated varieties, scientists find that they are related. DNA sequences also give evidence about how different the plants are and how long ago they diverged, forming new populations with different characteristics.

Scientists have looked for historical, archaeological, and geologic evidence to find out when and where crops like cabbage first appeared. For example, more than 2000 years ago the ancient Greeks wrote about growing cabbage. People have found seeds in the ruins of ancient cities, and have determined the ages of the seeds. Although traces of some wild mustards have been found in very ancient fossils, no traces of cabbage, cauliflower, or mooli have been found which are so ancient.

Recent evidence of the above types suggests that people may have first produced populations of cabbage from populations of wild mustard, then people produced populations of cauliflower from populations of cabbage, both through the process of artificial selection.

Why is this research important? Will it help us understand mustard and evaluate methods of selection, so that we can continue to produce new kinds of crops?

And how can we possibly know whether mustard with long roots was produced by natural selection due to floods?

Actually, that was just a hypothesis. We need to collect more evidence to know how good a hypothesis it is.

...And did those beetles really write that plan?

This book is written just to give you a few ideas.

Now it is up to you to ask questions, investigate further and find out more...